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(54) A method and a device for determining the dry weight of a patient with kidney failure

(57) The invention relates to a method and a device for monitoring the fluid status of a patient with kidney failure. In case of renal failure all forms of ingested fluid accumulate in body tissues causing increased stress on the circulatory system. This surplus fluid has to be removed during a dialysis treatment by ultrafiltration of the blood. The amount of this surplus fluid or the weight corrected for this surplus fluid, i.e. the dry weight, is an important parameter for managing the fluid status of a dialysis patient. According to the invention the dry weight $Wgt_{dry}(t)$ of a patient at a time t is determined by determining the extracellular water volume ECV(t) of the patient at the time t, by determining the weight Wgt(t) of the patient at the time t and by deriving the dry weight $Wgt_{dry}(t)$ of the patient as an intersection of a function derived from the determined ECV(t) and Wgt(t) values with a previously established extracellular water volume (ECV) against dry weight (Wgt_{dry}) reference relation representing healthy subjects. To obtain more accurate results it is also proposed to take into account a fat mass correction $\Delta f(t)$. The invention also relates to a device for deriving the dry weight $Wgt_{dry}(t)$.

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Description

[0001] The invention relates to a method and a device for monitoring the fluid status of a patient according to the preamble of claims 1 and 12, respectively.

[0002] The kidneys carry out several functions for maintaining the health of a human body. First, they control the fluid balance by separating any excess fluid from the patient's blood volume. Second, they serve to purify the blood from any waste substances like urea or creatinine. Last not least they also control the levels of certain substances in the blood like electrolytes in order to ensure a healthy and necessary concentration level.

[0003] In case of renal failure all forms of ingested fluid accumulate in body tissues causing increased stress on the circulatory system. This surplus fluid has to be removed during a dialysis treatment by ultrafiltration of the blood. If insufficient fluid is removed the long term consequenses can be severe, leading to high blood pressure and cardiac failure. Cardiac failure itself is many times more likely to occur in dialysis patients and it is thought that states of fluid overload are one of the major contributing factors. Removal of too much fluid is also dangerous since the dialysis patient becomes dehydrated and this invariably leads to hypotension.

[0004] The dry weight defines the weight of a patient that would be achieved if the kidneys were working normally. In other words this represents the optimal target weight (or fluid status) which should be achieved in order to minimise cardiovascular risk. Dry weight has always been an elusive problem in routine clinical practise due to lack of quantitative methods for its assessment. Currently the dry weight problem is approached using indirect indicators e.g. blood pressure, echocardiographic investigations and subjective information such as X-rays. Furthermore it has been particularly difficult to define a set of conditions which are universally accepted as the dry weight standard.

[0005] A promising method to derive the fluid status of a patient involves the use of bioimpedance measurements. A small alternating current is applied to two or more electrodes which are attached to a patient and the corresponding potential drop is measured. The various fluid compartments of a human body contribute differently to the measured signals. The use of multiple frequencies allows the intracellular water (ICV) and extracellular water (ECV) volumes to be determined. An example of such a device is described in the international patent application WO 92/19153. However, this document discloses no method regarding how the dry weight of the particular patient can be derived.

[0006] Hence there is a need for a non-invasive, accurate and easy to use method for dry weight assessment. This method would be of major benefit to the management of dialysis patients and could significantly reduce hospitalisation costs in the long term. It is hence an object of this invention to provide such a method.

[0007] According to the invention this problem is solved by a method for determining the dry weight $Wgt_{dry}(t)$ of a patient at a time t comprising the steps of determining the extracellular water volume ECV(t) of the patient at the time t, of determining the weight Wgt(t) of the patient at the time t and of deriving the dry weight $Wgt_{dry}(t)$ of the patient as an intersection of a function derived from the determined ECV(t) and Wgt(t) values with a previously established extracellular water volume (ECV) against dry weight (Wgt_{dry}) reference relation representing healthy subjects.

[0008] The inventive method is based on the observation that by looking at the ECV and the weight of a patient both values should approach the ECV and dry weight values of healthy subjects the longer a patient is being treated by renal replacement therapy, i.e. dialysis. Successive measurements therefore directly pinpoint to the intersection with the previously established ECV against Wgt_{dry} reference relation and thus to the dry weight of the patient being treated. In fact it has turned out that a first estimate can be obtained from a single reading for the ECV(t) and Wgt(t) values by deriving a function, most notably a straight line, which can directly be defined by the ECV(t) and Wgt(t) values. The intersection of this function with the ECV against Wgt_{dry} reference relation for healthy subjects can then easily be calculated and thus the dry weight $Wgt_{dry}(t)$ of the patient be derived.

[0009] In a preferred embodiment of the invention ECV(t) is derived by a bioimpedance measurement. The bioimpedance measurement may be a whole body or a segmental measurement.

[0010] In an embodiment of the invention which is particularly easy to apply, the intersection of the function derived from the determined ECV(t) and Wgt(t) values with the previously established ECV against Wgt_{dry} reference relation is determined by using the expression

$$Wgt_{Dry}(t) = \frac{ECV(t) - \beta_e \cdot Wgt(t)}{\alpha_e - \beta_e} \qquad (1),$$

wherein α_e and β_e are empirically determined coefficients. The coefficient α_e represents the slope of a previously established ECV against Wgt_{dry} reference line, and β_e is the slope of a straight line through the Wgt(t)/ECV(t) data pair.

[0011] An even more advantageous embodiment of the invention involves the storage of several $ECV(t_i)$ and $Wgt(t_i)$ values at times t_i, i=1...j, preferably between subsequent dialysis treatments. A more accurate estimate of the dry weight $Wgt_{dry}(t_j)$ is thus derived by a linear regression analysis.

[0012] A more refined embodiment of the invention determines a fat mass correction $\Delta f(t)$ in order to take into account

a variable fat mass for each patient. This fat mass correction $\Delta f(t)$ enables a more accurate comparison with the previously established ECV against Wgt_{dry} reference relation representing healthy subjects which should have been derived from fat mass corrected data as well in order to represent some kind of average fat mass contribution to the dry body weight Wgt_{dry}.

[0013] In a preferred embodiment of the invention the dry body weight $Wgt_{dry}(t)$ is derived by employing a correction term to equation (1) which is dependent on $\Delta f(t)$:

$$Wgt_{Dry}(t) = \frac{ECV(t) - \beta_e \cdot Wgt(t)}{\alpha_e - \beta_e} - \frac{\alpha_e \cdot \Delta f(t)}{\beta_e - \alpha_e} \qquad (2).$$

[0014] The fat mass correction $\Delta f(t)$ is preferably derived with the help of a measurement of the intracellular water volume ICV(t) of the patient at the time t. As indicated above the ICV(t) and ECV(t) values can be determined simultaneously by the same measurement process.

[0015] In a further mode of the invention the fat mass correction $\Delta f(t)$ is determined from the ICV(t) and ECV(t) values according to equation (3):

$$\Delta f(t) = Wgt(t) - \frac{(1 - \rho_e \cdot \alpha_e - \rho_i \cdot \alpha_i) \cdot ICV(t)}{\alpha_i} - \rho_i \cdot ICV(t) - \rho_e \cdot ECV(t) \qquad (3),$$

where α_i is a further empirical coefficient, and ρ_e and ρ_i are the densities of the ECV and the ICV compartments, respectively (~ 1 kg/litre).

[0016] It is also an object of the invention to provide a device for a non-invasive, accurate and easy to use dry weight assessment. The invention therefore also concerns a device comprising a microprocessor unit which in turn comprises a microprocessor program storage unit, an input unit to enable the values of ECV(t) and Wgt(t) to be entered into the device, and a computer storage unit for storing the ECV(t) and Wgt(t) values, wherein the microprocessor program storage unit comprises a program for deriving the dry weight $Wgt_{dry}(t)$ from an intersection of a function derived from the stored ECV(t) and Wgt(t) values with a previously established ECV against Wgt_{dry} reference relation representing healthy subjects.

[0017] In a preferred embodiment of the invention the device further comprises means for determining the ECV(t) value and/or the Wgt(t) value. The means for determining the ECV(t) value may be a bioimpedance device, applied in a whole body or segmental measurement mode.

[0018] The input unit may be a manual user interface such as a keyboard in order to enable the input of the ECV(t) and Wgt(t) values. In a particularly convienient embodiment the means for determining the ECV(t) value and/or the means for determining the Wgt(t) value are directly linked to the input unit which contains a corresponding interface in this case. The manual input of these values is then no longer necessary.

[0019] In further embodiments of the invention the program in the microprocessor storage unit employs equation (1) or a linear regression analysis as outlined above in order to derive the dry weight $Wgt_{dry}(t)$.

[0020] A further improved mode of the device according of the invention makes use of a fat mass correction $\Delta f(t)$ as described in equation (2). For the determination of $\Delta f(t)$ the device may also comprise means for determining the ICV (t) value, preferably a bioimpedance device which simultanously measures the ECV(t) and ICV(t) values. In this device the input unit also enables entering the ICV(t) value and the computer storage unit is able to store the ICV(t) value. The program for deriving the dry body weight $Wgt_{dry}(t)$ is then determining the fat mass correction $\Delta f(t)$ by using this ICV(t) value. For this purpose equation (3) may be implemented in the program.

[0021] For an improved understanding of the invention an embodiment will be described purely by way of a non-restrictive example with reference to the appended drawings in which

Figure 1 shows an illustration of typical body composition ratios of the human body;

Figure 2 schematically shows an embodiment of a device for determining the dry weight of a patient according to the invention;

Figure 3a shows a bioimpedance electrode arrangement for whole body bioimpedance measurements;

Figure 3b shows a bioimpedance electrode arrangement for segmental body bioimpedance measurements;

Figure 4 shows an illustration of a bioimpedance measurement for determining the ECV and/or ICV contributions;

Figure 5a shows an ECV against weight diagram graphically illustrating the finding of the dry weight $Wgt_{dry}(t)$ according to the invention;

Figure 5b shows an ECV against weight diagram with subsequent $Wgt(t_i)/ECV(t_i)$ measurements for a dialysis patient (triangles) with a straight line obtained by regression analysis and the corresponding finding of the dry weight $Wgt_{dry}(t)$ according to the invention; and

Figure 6 shows an ECV against weight diagram graphically illustrating the influence of a fat mass correction term $\Delta f(t)$.

[0022] The composition of the human body can be described by a number of compartments which may be expressed as typical fractions of the total body weight as indicated in Figure 1. In patients with kidney failure the ECV becomes expanded due to the ingestion of water. Other compartments are thought to be largely unaffected by changes in a patient's fluid status. Consequently measurement of the ECV is clearly a useful parameter which could help with dry weight management.

[0023] In order to support normal homeostasis a minimum ECV must be required for a given weight. Hence to a good approximation ECV is linearly proportional to weight and may be determined via prediction formulae. According to Guyton physiology (A.C. Guyton: Textbook of Medical Physiology, W.B. Saunders Company, 1991) there is approximately 15 litres of ECV for a weight of 70 kg for a healthy subject with normal fluid and nutrition status. New investigations on healthy subjects revealed the following reference relation between measured ECV_m and measured Wgt_{dry}:

$$ECV_m + ECV_{offset} = \alpha_e \cdot Wgt_{dry} \qquad (4),$$

with α_e = 0,2146 litres/kg and ECV_{offset} = -0,93 litres. The value for α_e expressed as a ratio is 15,002/70. This is very close to the relationship given by Guyton physiology. The offset ECV_{offset} has been proven to improve the accuracy. As all body compartments shown in Figure 2 should be proportional to Wgt_{dry} it is useful to rewrite equation (4) with a corrected $ECV = ECV_m + ECV_{offset}$. Equation (4a) which is thus obtained represents a straight line passing the origin in a ECV against Wgt_{dry} diagram:

$$ECV = \alpha_e \cdot Wgt_{dry} \qquad (4a).$$

[0024] The invention is based on the observation that dialysis patients have an expanded ECV and that therefore the measured ECV must be higher for a given weight than for healthy subjects. If the weight of a fluid overloaded dialysis patient is reduced over many treatments by removal of fluid then the measured ECV should fall, too. Eventually the ECV of the dialysis patient should converge to or close to that of a healthy subject with no renal failure.

[0025] An embodiment of a device for determining the dry weight Wgt_{dry} of a patient according to the invention is shown in Figure 2. The device 10 comprises a microprocessor unit 1 which in turn comprises a microprocessor program storage unit 1a. By means of a link 4 the microprocessor unit 1 is connected to an input unit 2 and a computer storage unit 3. A program for deriving the dry weight $Wgt_{dry}(t)$ of a patient at a time t is stored in the microprocessor program storage unit 1a.

[0026] According to the invention the dry weight $Wgt_{dry}(t)$ is derived as follows: The extracellular water volume ECV (t) of the patient at the time t is determined and entered into the input unit 2 which passes the value to the computer storage unit 3 where it is stored. If equation (4b) is used as reference line, the offset ECV_{offset} as outlined in equation (4) has to be added by the microprocessor program to ECV(t) before the value is stored in order to have comparable data. If equation (4) is used this offset correction is not necessary.

[0027] The weight Wgt(t) of the patient at the time t is also determined and processed similarly. The program for deriving the dry weight $Wgt_{dry}(t)$ is capable of calculating an intersection between a function derived from the stored ECV(t) and Wgt(t) values and the previously established ECV against Wgt_{dry} reference line representing healthy subjects according to equation (4) or (4a), respectively. The function derived from the stored ECV(t) and Wgt(t) values reflects the fact that these values can only change in a particular manner in the predicted progress of dialysis therapy.

[0028] To determine the ECV(t) value means 5 are provided which are connected to the input unit 2 by a link 6. The means 5 is a bioimpedance measurement device. For the bioimpedance measurement various electrode arrangements are possible. In Figure 2 only two electrode elements 5a and 5b are attached to the bioimpedance measurement device 5. Each of the electrode units 5a and 5b consists of a current injection electrode and a potential pick up electrode (not shown). By applying the two electrode units 5a and 5b to the wrist and the ankle of a patient, respectively, as outlined

In Figure 3a, the wholy body impedance may be determined. Under this electrode configuration the body is assumed to be a homogenous cylinder. However by use of electrodes on limbs, segmental sections of the body may be isolated allowing localised volume measurements. This has the advantage that localised volume measurements are possible and an improved accuracy in the determination of the whole body fluid status may be achieved. Such a configuration is displayed in Figure 3b. Additional electrode units 5a' and 5b' are attached close to the corresponding shoulder and the hip of the patient enabling a segmental approach to the body elements leg, arm and trunk.

[0029] The ECV(t) value is determined by exploiting the fact that the electrical impedance of body tissue changes as currents of different alternating frequencies are applied to the patient via the electrodes. At low frequencies the cells behave as insulators and the applied current passes only through the ECV spaces. At high frequencies the cells become conductive and thus current passes through both the ICV and ECV spaces. This is illustrated in Figure 4. Measurement of the impedance over at least two frequencies, better over a range of frequencies, allows an impedance locus to be constructed from which the resistance of the ICV and ECV components may be determined. Hence the volumes of the respective compartments can then be calculated from the resistance information, based on compartment resistivity constants available from prior studies for which the volumes were also determined by dilution measurements.

[0030] A bioimpedance device performing such calculations is distributed by Xitron Technologies under the trademark Hydra™. Details about this device are disclosed in the international patent application WO 92/19153.

[0031] An advantage of a first mode of the invention is that only ECV values need to be determined. Therefore only measurements at frequencies being low enough are necessary which have negligible contributions from the ICV compartment. Due to this fact the ECV values can be determined much more accurately than the ICV values for which frequencies are necessary which always lead to contributions from both compartments.

[0032] Other methods proposed in the art address the fluid status of a patient by involving the ICV compartment as well, like analyzing ratios of the kind ECV/(ECV+ICV) or ECV/ICV. Since there is always a discussion how well the impedance locus represents the different compartments such approaches inherently contain deficiencies which are avoided by the claimed invention as no simultaneous analysis of the two compartments remains necessary. (In fact the ICV value may instead be used for a second order correction as will be described below.)

[0033] Returning to the embodiment shown in Figure 2, means 7 are also provided for determining the weight Wgt (t) of the patient which are connected to the input unit 2 by a link 8. The means 7 consist of a scales device which are well known in the art.

[0034] In the embodiment shown in Figure 2 the input unit 2 contains an interface by which the values for ECV(t) and Wgt(t) are directly transfered via the link 4 to the computer storage unit 3. It may also be possible that the determined values for ECV(t) and Wgt(t) are manually entered into the input unit 2 by a user.

[0035] The procedure according to which the program stored in the microprocessor program storage unit 1a derives the dry weight $Wgt_{dry}(t)$ is illustrated in Figure 5a: In this figure the reference relation between the ECV and Wgt_{dry} for healthy subjects is given as a straight line with slope α_e according to equation (4) or (4a), respectively.

[0036] A single Wgt(t) and ECV(t) measurement of a dialysis patient is denoted by the offline circle. The program for deriving the dry weight $Wgt_{dry}(t)$ of the dialysis patient is now using equation (1) to derive $Wgt_{dry}(t)$. This equation represents the calculation of the intersection IS of a line through the Wgt(t)/ECV(t) data point with the reference line. This line has the slope β_e. This slope is expected to be close to $1/\rho_e$, i.e. in a first estimate the program uses $\beta_e = 1$ litre/kg. The weight coordinate of the intersection directly gives the sought $Wgt_{dry}(t)$ value.

[0037] Figure 5b shows the ECV(t) and Wgt(t) values for a single patient between several subsequent dialysis treatments (triangles), the measurements being made directly before the beginning of a dialysis treatment (pre-dialysis). By successive reduction in post dialysis weight the Wgt(t)/ECV(t) measurement pairs shift increasingly closer to the values predicted for a healthy subject indicating a progressive improvement in the fluid status of the patient. To improve the accuracy of the calculated $Wgt_{dry}(t)$ value a straight line may be fitted to the Wgt(t)/ECV(t) measurement pairs by linear regression analysis. In fact these straight lines turned out to have a slope of approximately 1 litre/1 kg, suggesting that most of the excess fluid accumulated and hence weight gain is really sequestered in the ECV compartment. As in the case of a single measurement pair the intersection IS of the straight line with the ECV against Wgt_{dry} reference for healthy subjects directly identifies the dry weight $Wgt_{dry}(t)$ of the patient. In Figure 5b one obtains a value of $Wgt_{dry}(t) = 81.6$ kg using this method.

[0038] The computer storage unit 3 of the device 10 is hence also able to store $Wgt(t_i)/ECV(t_i)$ data pairs for various times t_i, which are preferably be aquired directly before subsequent dialysis treatments i=1...j, as represented by the measurements shown in Figure 5b. The program for deriving the dry weight $Wgt_{dry}(t_j)$ at the latest time t_j is then able to retrieve all $Wgt(t_i)/ECV(t_i)$ data pairs from the computer storage unit 3. Depending on the scatter of the data the program performs a linear regression analysis either with the contraint that the slope β_e has a fixed value (e.g. $\beta_e = 1$ litre/kg) or not, or both to offer the user the results of both calculations. Taking an arbitrary Wgt/ECV data pair on the derived straight line function for ECV(t) and Wgt(t) in equation (1), the dry weight $Wgt_{dry}(t_j)$ is determined with the help of equation (1) as well. Further statistical information (e.g., correlation coefficients etc.) as is known in the art of regression analysis may be provided in addition.

[0039] In order to further improve the accuracy of the derived dry weight $Wgt_{dry}(t)$ the program stored in the microprocessor program storage unit 1a has a further section which takes a fat mass correction $\Delta f(t)$ into account. The dry weight $Wgt_{dry}(t)$ is then calculated according to equation (2). The influence of the fat mass correction $\Delta f(t)$ is illustrated by Figure 1: Apart from the ECV and ICV contributions to the total body weight the next most important contribution is attributed to fat mass. Other compartments are an order of magnitude less relevant. For the sake of simplicity, all remaining body mass which is neither ECV nor ICV may be regarded as "the fat mass compartment". The fat mass correction $\Delta f(t)$ originates from this compartment. It is this particular compartment which may vary considerably from subject to subject, for healthy subjects as well as for dialysis patients. This variation will lead to some error in the $Wgt_{dry}(t)$ data if it is not considered. In fact the reference line according to equation (4) has been established by normalizing the weight data in healthy subjects by taking Δf into account.

[0040] Refering to Figure 6 the impact of $\Delta f(t)$ becomes apparent: Taking the reference line of healthy subjects with slope α_e and the middle line of the three lines with slope β_e, one would have the same situation as in Figure 5a. In case the dialysis patient does not have a "normal body fat mass", the weight Wgt(t) of the patient is shifted to the left or to the right by the fat mass correction $\Delta f(t)$, depending on whether the patient has a reduced or an increased body fat mass, respectively. In the latter two cases the intersection IS' and IS" would lead to an inaccurate dry weight $Wgt_{dry}(t)$ value. Instead the dry weight $Wgt_{dry}(t)$ is given by the weight values of the respective circled data points, i.e. an amount e_{DW} has to be added or subtracted from the calculated intersection weight value. This amount e_{DW} is given by the second term in equation (2), by which equation (2) differs from the simplified equation (1).

[0041] In order to derive the fat mass correction $\Delta f(t)$ itself, the program makes use of equation (3). For this purpose the means 5 for determining the ECV(t) value is also a means for determining the ICV(t) value. As has been outlined above there are devices available on the market which measure both values simultanously.

[0042] Equation (3) is based on the following relations: A relation similar to equations (4) and (4a) can be defined between the ICV and Wgt_{dry} for healthy subjects, i.e.

$$ICV_m + ICV_{offset} = \alpha_i \cdot Wgt_{dry} \quad (5),$$

and

$$ICV = \alpha_i \cdot Wgt_{dry} \quad (5a),$$

where the same comments apply to the offset ICV_{offset} as for the offset ECV_{offset}. A survey has revealed the following values of the coefficients: $\alpha_i = 0{,}3297$ litres/kg, $ICV_{offset} = 2{,}63$ litres. Again the slope α_i, - expressed as a ratio: 23,079/70 litres/kg - is not too dissimilar to Guyton physiology (26/70 litres/kg, see Figure 1).

[0043] The values - as in the determination of the values of the coefficents of equation (4) - have been found in an optimization strategy to fit measured weights of healthy subject to a sum of the ECV, the ICV and the fat mass compartments. The latter is in turn divided into an average fat mass and an individual fat mass correction Δf compartment. The volume of the fat mass correction Δf compartment was the only free parameter for a given measured total weight during the optimization calculation which took into account the individuality of the various healthy subjects.

[0044] Furthermore its has been revealed in this study that the ICV volumes do not significantly differ from treatment to treatment for a dialysis patient. In case the patient is neither catabolic or anabolic this volume should even be identical to the ICV volumes of heathly subjects. After having established the coefficients of equation (5) it is therefore possible to devide the total body mass of a dialysis patient into the ICV part which can be determined by the measured ICV(t) value multiplied by the corresponding density ρ_i, into the ECV part which can be determined by the measured ECV(t) value multiplied by the corresponding density ρ_e and which is the sum of a part ECV_N representing the healthy value and a deviation e_{ECV} which accounts for the disturbed fluid balance in a dialysis patient (see Figure 6), the average fat mass contribution and, last not least, the fat mass correction $\Delta f(t)$. The average mass contribution is not a free parameter in the calculation as it can be expressed as dry body weight of average and healthy subjects minus the ICV and ECV contributions of these subjects. The dry body weight of a healthy and average subjects is then substituted by an according arrangement of equation (5a). As a result equation (3) is found where $\Delta f(t)$ remains the only unknown parameter.

[0045] In the derivation of equation (3) the equations (4a) and (5a) were used instead of equations (4) and (5), respectively, i.e. the ECV(t) and ICV(t) values used in equation (3) have to corrected values in view of the offsets ECV_{offset} and ICV_{offset}. For the densities ρ_e and ρ_i the program uses 1 kg/litre as these compartments basically consist of water.

[0046] For patients who just start dialysis therapy show ICV volumes that are slightly increased compared with the

rather steady values found after some dialysis treatments. The outlined procedure to determine the fat mass correction $\Delta f(t)$ is however still a good approximation even in this case.

[0047] Independent of whether a fat mass correction $\Delta f(t)$ is taken into account or not, the result for $Wgt_{dry}(t)$ is finally passed on to an output unit 9 which is a display device and which displays the result to a user. Further intermediate results like the measurement values or the fat mass correction $\Delta f(t)$ might add to the informative character of the display.

[0048] The disclosed device and method according to the invention is hence able to provide for a powerful technique for the management of dry weight. It is obvious that the scope of the claimed invention is not limited to the equation (4) as far as the previously established ECV against Wgt_{dry} reference relation for healthy subjects is concerned. Any other established relation can be used instead.

[0049] Management of any patient is possible, independent of the treatment modality, i.e. the invention is applicable for hemodialysis, hemofiltration, hemodiafiltration or any forms of peritoneal dialysis (all these treatment modalities are summarized throughout this patent application by the terminology "a dialysis treatment"). Furthermore, measurement in virtually any setting would be practical including the home, clinic, dialysis unit, ward or intensive care environment.

Claims

1. A method for determining the dry weight $Wgt_{dry}(t)$ of a patient at a time t comprising the steps of:

   determining the extracellular water volume ECV(t) of the patient at the time t,

   determining the weight Wgt(t) of the patient at the time t,

   deriving the dry weight $Wgt_{dry}(t)$ of the patient as an intersection of a function derived from the determined ECV(t) and Wgt(t) values with a previously established extracellular water volume (ECV) against dry weight (Wgt_{dry}) reference relation representing healthy subjects.

2. The method according to claim 1 **characterized in that** ECV(t) is derived from a bioimpedance measurement.

3. The method according to claim 2 **characterized in that** the bioimpedance measurement is a whole body measurement.

4. The method according to claim 2 **characterized in that** the bioimpedance measurement is a segmental measurement.

5. The method according to any of the preceding claims **characterized in that** $Wgt_{dry}(t)$ is determined using the following expression:

$$Wgt_{Dry}(t) = \frac{ECV(t) - \beta_e \cdot Wgt(t)}{\alpha_e - \beta_e}$$

   where α_e and β_e are empirically determined coefficients.

6. The method according to any of the preceding claims **characterized in that** the $ECV(t_i)$ and $Wgt(t_i)$ values of a patient at times t_j, i=1...j, are stored and that the dry body weight $Wgt_{dry}(t_j)$ is derived by a linear regression analysis.

7. The method according to any of the preceding claims **characterized in that** a fat mass correction $\Delta f(t)$ is determined in order to derive the dry body weight $Wgt_{dry}(t)$ from the determined weight Wgt(t).

8. The method according to claim 7 **characterized in that** the dry weight $Wgt_{dry}(t)$ is derived by the following expression:

$$Wgt_{Dry}(t) = \frac{ECV(t) - \beta_e \cdot Wgt(t)}{\alpha_e - \beta_e} - \frac{\alpha_e \cdot \Delta f(t)}{\beta_e - \alpha_e},$$

   where α_e and β_e are empirically determined coefficients.

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9. The method according to claims 5 or 8 **characterized in that** α_e equals 0,2146 litres/kg and β_e equals 1 litre/kg.

10. The method according to any of the claim 7 to 8 **characterized in that** the intracellular water volume ICV(t) is determined for the patient at the time t and that the determined ICV(t) is used to derive the fat mass correction $\Delta f(t)$.

11. The method according to claim 10 **characterized in that** the fat mass correction $\Delta f(t)$ is derived by the following expression:

$$\Delta f(t) = Wgt(t) - \frac{(1-\rho_e \cdot \alpha_e - \rho_i \cdot \alpha_i) \cdot ICV(t)}{\alpha_i} - \rho_i \cdot ICV(t) - \rho_e \cdot ECV(t),$$

where ρ_e and ρ_i are the densities of the ECV(t) and ICV(t) volumes, respectively, and α_e is an empirically determined coefficients as in claim 8 and α_i is a further empirically determined coefficient.

12. A device (10) for carrying out the method according to claim 1 comprising

a microprocessor unit (1) which in turn comprises a microprocessor program storage unit (1 a),

a input unit (2) to enable entering the values of ECV(t) and Wgt(t),

a computer storage unit (3) for storing the ECV(t) and Wgt(t) values,
wherein the microprocessor program storage unit (1a) comprises a program for deriving the dry weight Wgt_{dry} (t) as an intersection (IS) of a function derived from the stored ECV(t) and Wgt(t) values with a previously established ECV against Wgt_{dry} reference relation representing healthy subjects.

13. The device according to claim 12 **characterized in that** it further comprises means (5) for determining the ECV (t) value.

14. The device according to claims 12 or 13 **characterized in that** it further comprises means (7) for determining the Wgt(t) value.

15. The device according to claim 13 **characterized in that** the means (5) for determining the ECV(t) value is a bio-impedance measurement device.

16. The device according to claim 12 **characterized in that** the input unit (2) is a manual user interface, preferably a keyboard.

17. The device according to any of the claims 12 to 16 **characterized in that** the input unit (2) comprises an interface to the means (5) for determining the ECV(t) value and/or the means (7) for determining the Wgt(t) value.

18. The device according to any of the claims 12 to 17 **characterized in that** the program for deriving the dry body weight $Wgt_{dry}(t)$ uses the following expression:

$$Wgt_{Dry}(t) = \frac{ECV(t) - \beta_e \cdot Wgt(t)}{\alpha_e - \beta_e},$$

where α_e and β_e are empirically determined coefficients.

19. The device according to any of the claims 12 to 18 **characterized in that** the computer storage unit (3) is capable of storing the $ECV(t_i)$ and $Wgt(t_i)$ values of a patient at times t_i, i=1...j, and that the program for deriving the dry weight $Wgt_{dry}(t_j)$ uses a linear regression analysis.

20. The device according to any of the claims 12 to 19 further comprising an output unit (9) that is linked to the microprocessor unit for outputting, preferably displaying the derived $Wgt_{dry}(t)$ value.

21. The device according to any of the claims 12 to 20 **characterized in that** the program stored in the microprocessor

program storage unit (1a) is suitable to determine a fat mass correction $\Delta f(t)$ in order to derive the dry body weight $Wgt_{dry}(t)$ from the deterimined weight Wgt(t).

22. The device according to claim 21 **characterized in that** the program for deriving the dry body weight $Wgt_{dry}(t)$ uses the following expression:

$$Wgt_{Dry}(t)=\frac{ECV(t)-\beta_e \cdot Wgt(t)}{\alpha_e-\beta_e} - \frac{\alpha_e \cdot \Delta f(t)}{\beta_e-\alpha_e},$$

where α_e, and β_e are empirically determined coefficients.

23. The device according to claims 18 or 22 **characterized in that** α_e equals 0,2146 litres/kg and β_e equals 1 litre/1 kg.

24. The device according to any of the claims 21 to 23 **characterized in that** the input unit (2) is also suitable to enable entering a value for the intracellular water volume ICV(t) of the patient at the time t, the computer storage unit (3) is able to store the ICV(t) value and that the program for deriving the dry body weight $Wgt_{dry}(t)$ uses the ICV(t) value in order to determine the fat mass correction $\Delta f(t)$.

25. The device according to claim 24 **characterized in that** the program uses the following expression for determining the fat mass correction $\Delta f(t)$:

$$\Delta f(t) = Wgt(t) - \frac{(1-\rho_e \cdot \alpha_e - \rho_I \cdot \alpha_I) \cdot ICV(t)}{\alpha_I} - \rho_I \cdot ICV(t) - \rho_e \cdot ECV(t),$$

where ρ_e and ρ_I are the densities of the ECV(t) and ICV(t) volumes, respectively, and α_e is an empirically determined coefficients as in claim 22 and α_I is a further empirically determined coefficient.

26. The device according to claims 24 or 26 **characterized in that** the device further comprises means for determining the ICV(t) value, preferably a bioimpedance device.

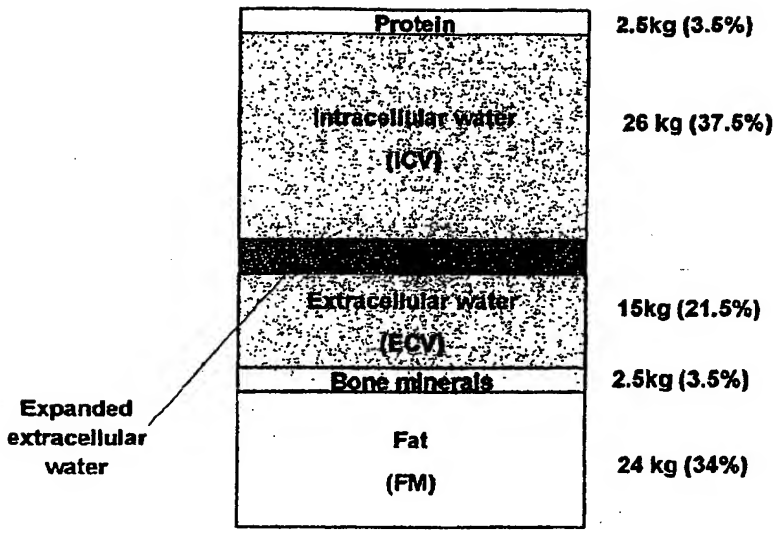

Figure 1

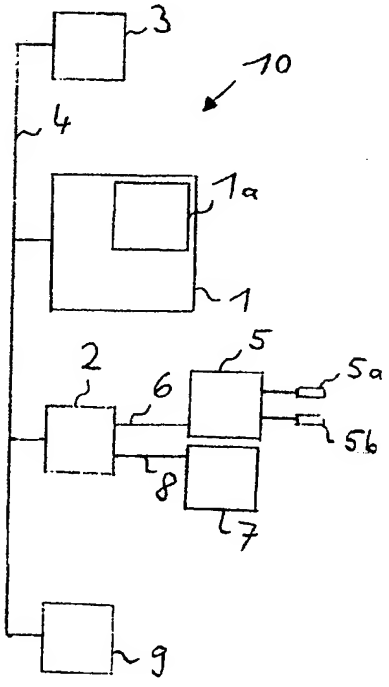

Figure 2

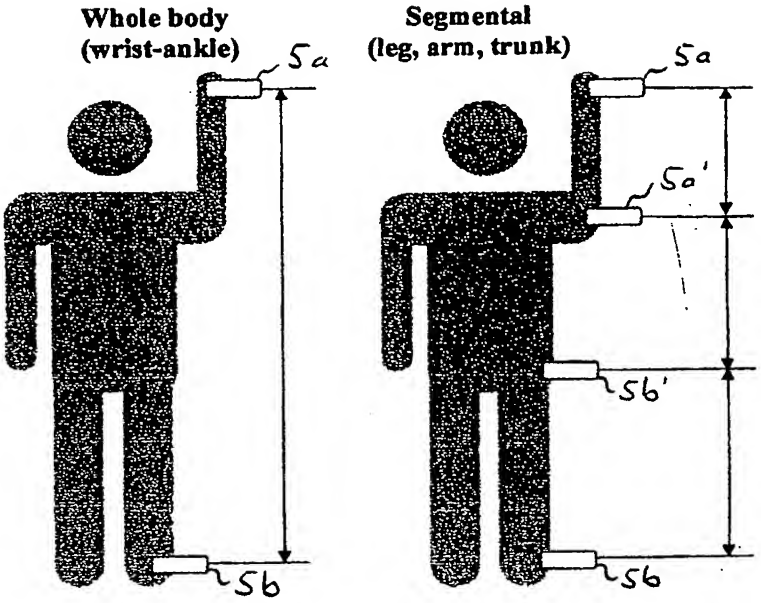

Figure 3a

Figure 3b

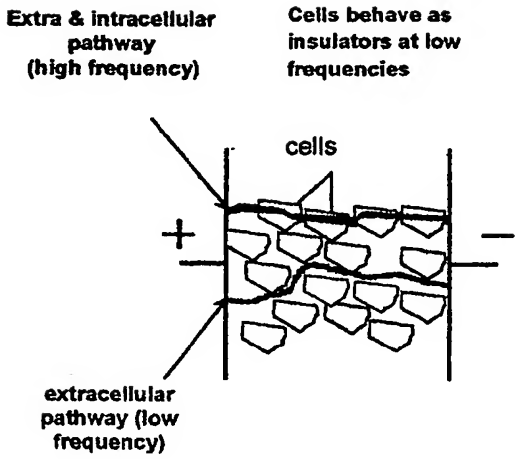

Figure 4

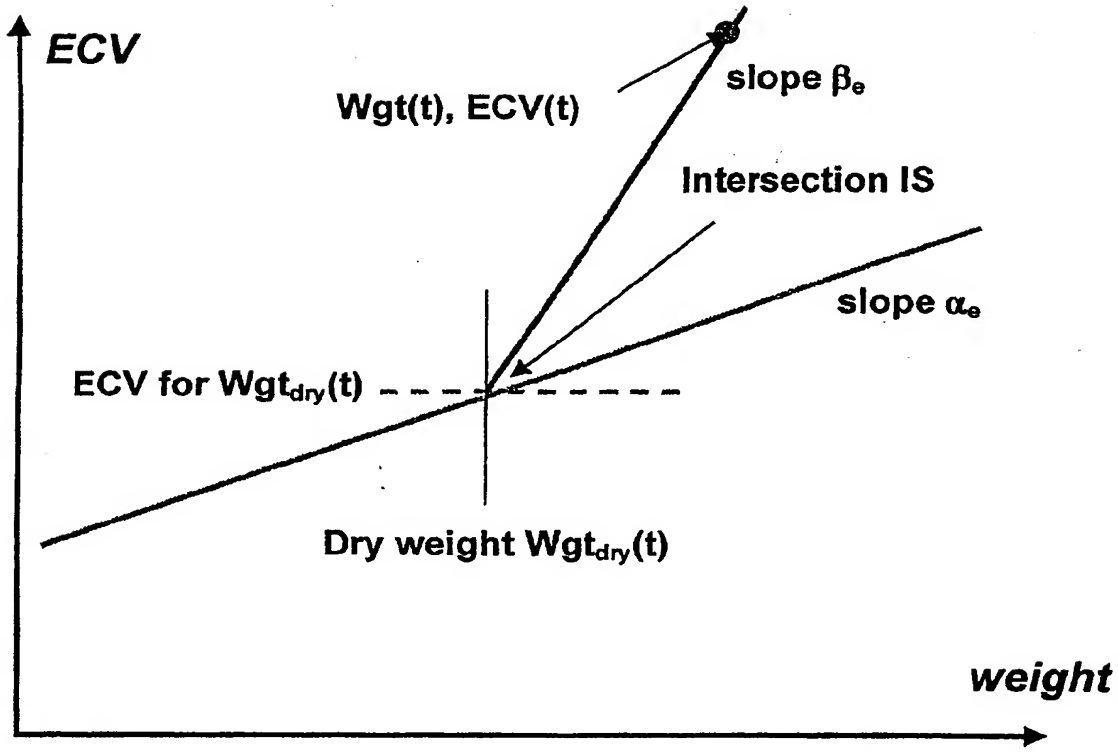

Figure 5a

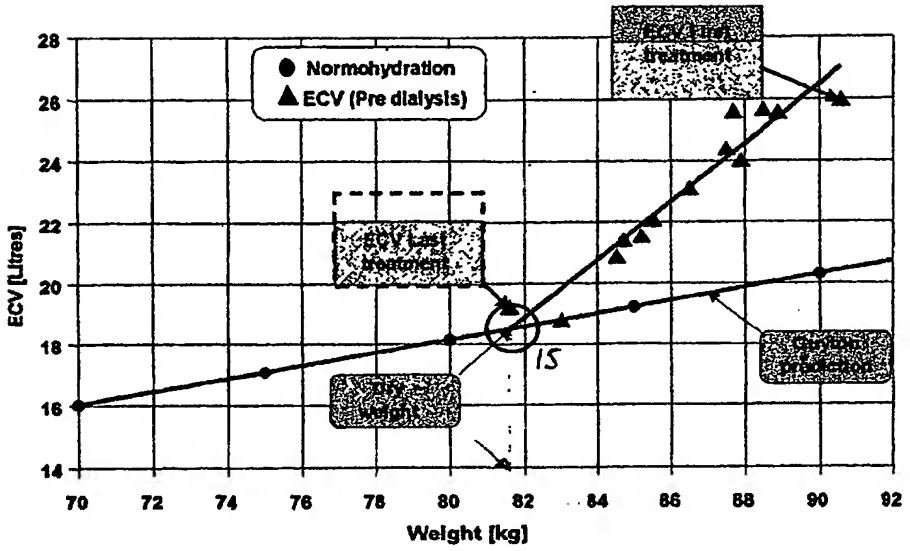

Figure 5b

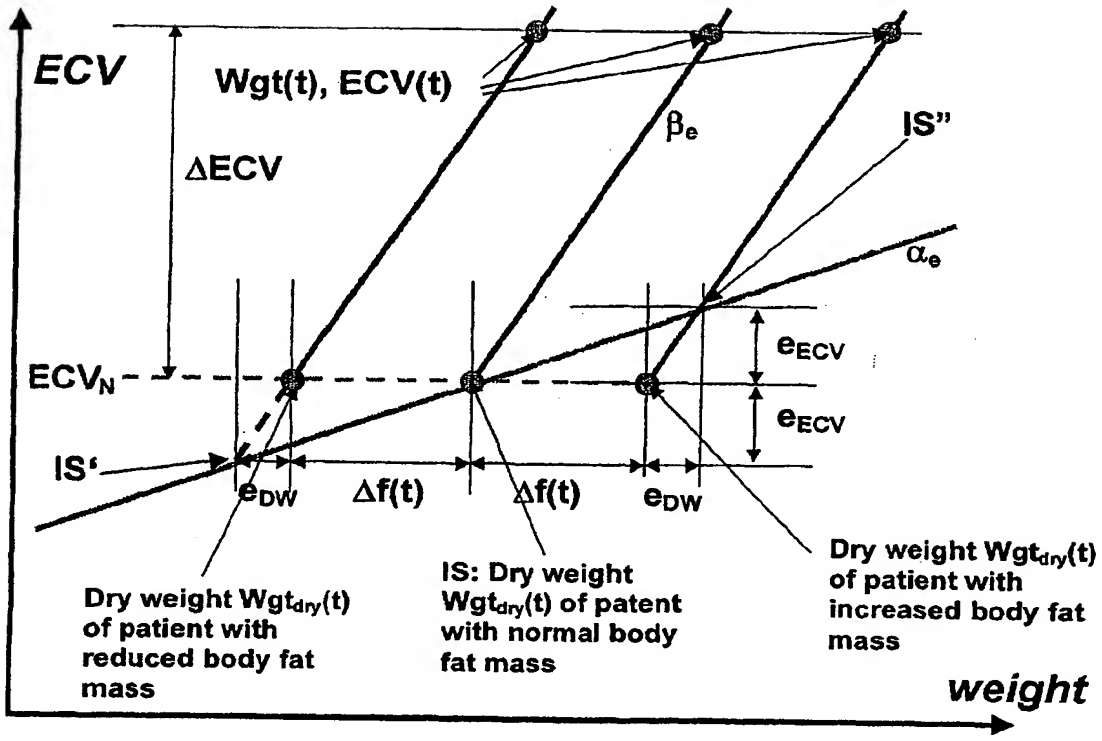

Figure 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 12 4111

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	EP 0 865 763 A (NTE S A) 23 September 1998 (1998-09-23) * column 12, line 50 - column 14, line 30 * * column 11, line 18 - column 12, line 14; tables 4-7 * ---	1-4,6,7, 10, 12-17, 19-21, 24,26	A61B5/05
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 12, 25 December 1997 (1997-12-25) & JP 09 220209 A (SEKISUI CHEM CO LTD), 26 August 1997 (1997-08-26) * abstract * ---	1-4,6, 12-17, 19,20, 24,26	
A	US 5 086 781 A (BOOKSPAN MARK A) 11 February 1992 (1992-02-11) * abstract * * column 4, line 16 - column 10, line 14; tables 1,2 * ---	1,2,4,6, 10, 12-17, 19,20, 24,26	TECHNICAL FIELDS SEARCHED (Int.Cl.7) A61B
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	7 March 2001	Weihs, J

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82